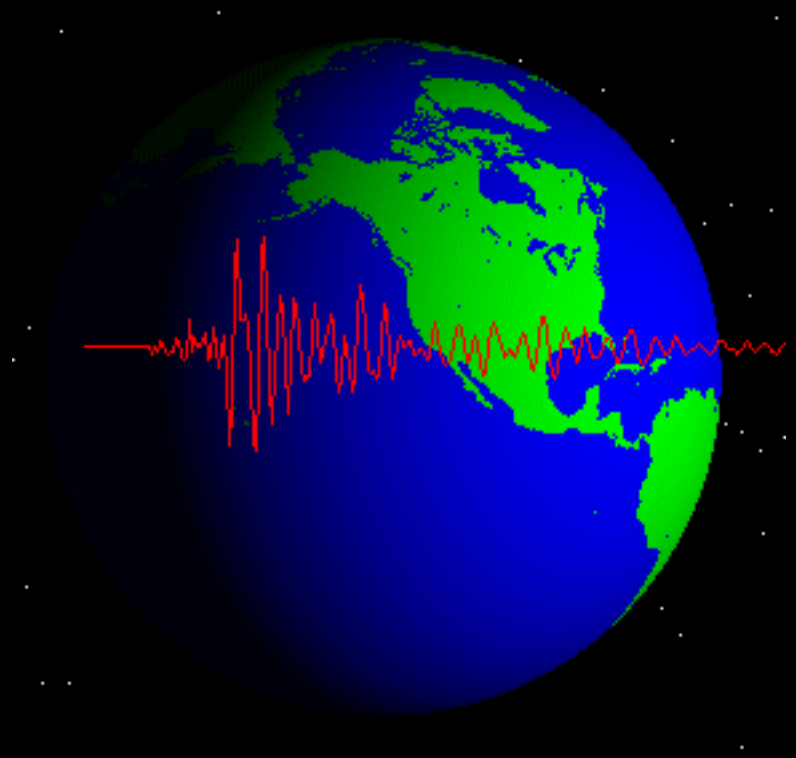
Learning Objectives (LO)



Lecture 15: Earthquakes
Read: Chapter 11
Homework #13 due Tuesday 12pm

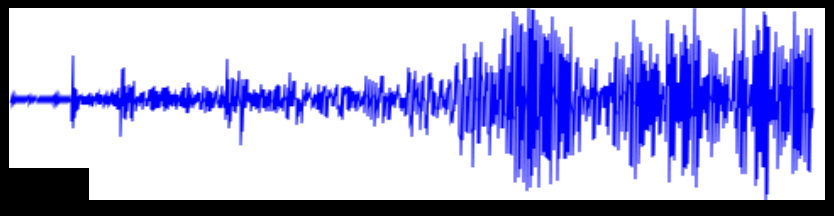
What we'll learn today:

1. Describe different earthquake hazards
2. List 4 types of seismic waves
3. Describe how seismic wave characteristics result in shadow zones
4. Describe seismic tomography and what it reveals about Earth's interior

Why do earthquakes cause damage?

Santa Cruz Mts., CA

Loma Prieta, 1989



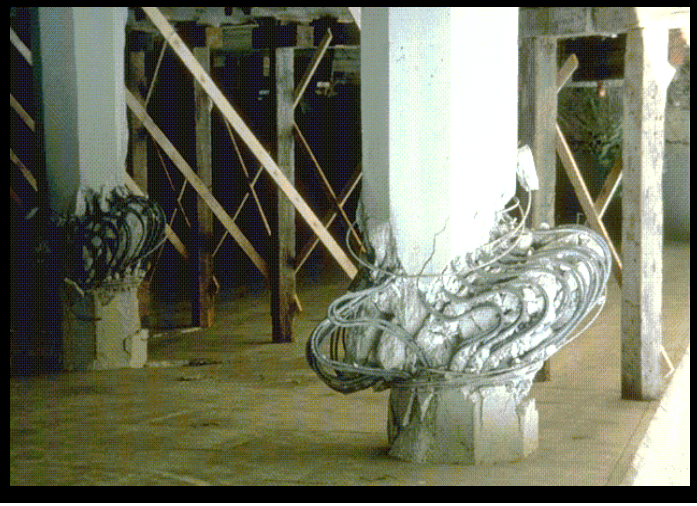
Earthquake Damage

Sichuan, China (2008, Mag. 7.9): 87,000 deaths
Many deaths due to ground shaking and structure collapse

Factors that determine level of destruction

- Proximity (how close)
- Intensity of quake
- Duration of quake
- Building design
- Nature of the ground (rocks)

LA mountains, 1994



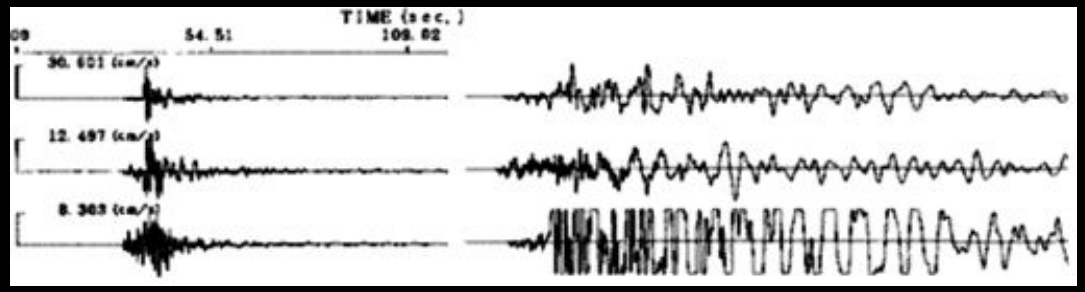
Oakland, 1989

Strong Motion Shaking

Liquefaction

- Strong shaking will cause wet soil to behave **temporarily** like a liquid, not a solid

Kobe, Japan Earthquake



hard rock wet, soft soil

- Places where liquefaction is a serious hazard:
  - Marina District (San Francisco)
  - LA basin
  - Mexico City
  - Kobe, Japan

Liquefaction

Fire is a major hazard after earthquakes

Kobe, Japan (1995, Mag. 7.2) 6400 deaths

San Francisco Earthquake
(1906, Mag. 7.9)

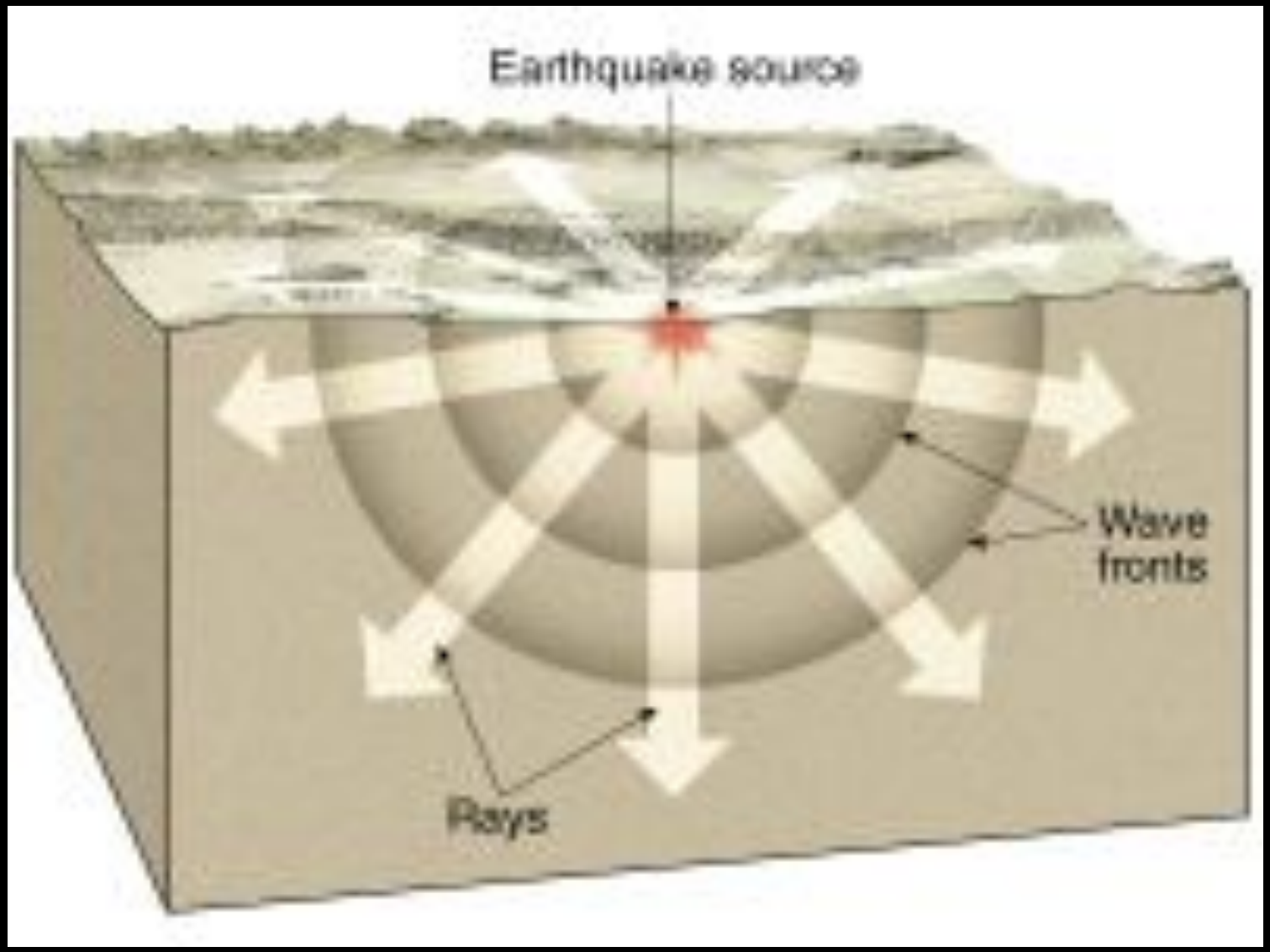
- 3000 deaths
- 80% of San Francisco destroyed

Landslides are a major hazard from earthquakes

Kashmir, Pakistan (2005, Mag. 7.6): 75,000 deaths

Tsunamis are a major hazard from earthquakes

Earthquakes generate seismic waves



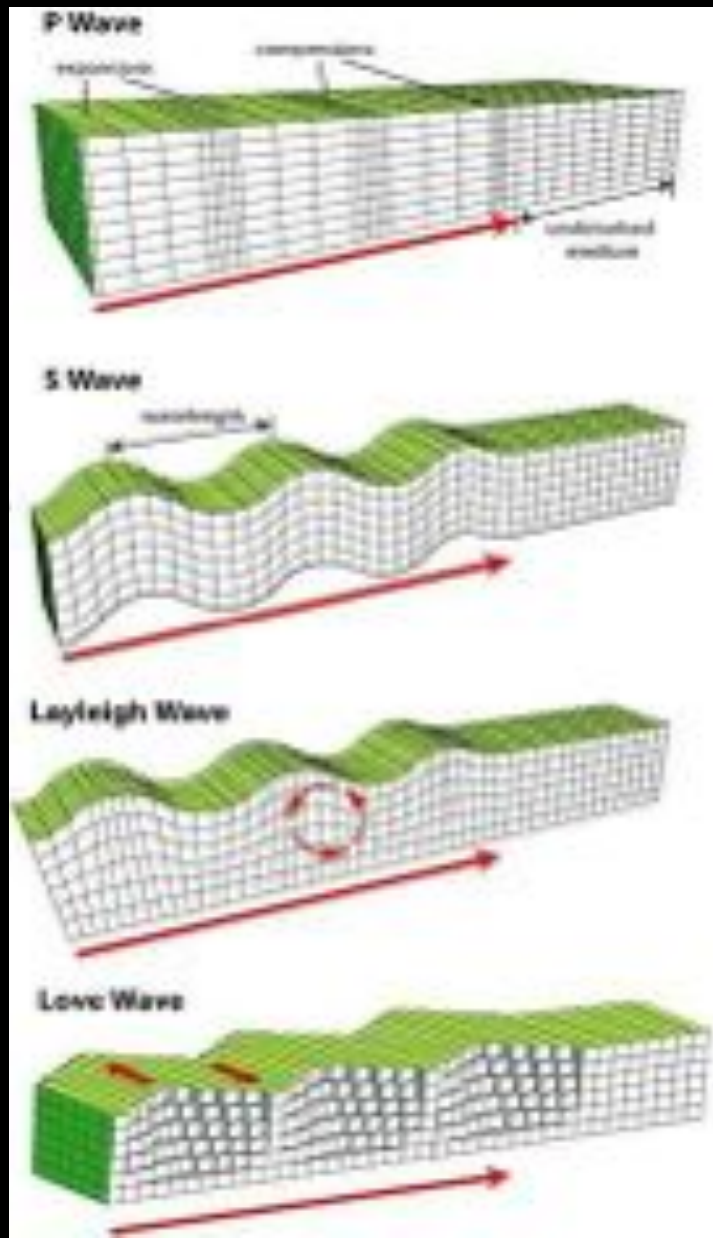
Two Types of Seismic Waves

1. **Body Waves:** travel through the body of the Earth (P & S)

- Waves compress and pull rocks in the direction of movement,
- Change the **volume** & **shape** of material

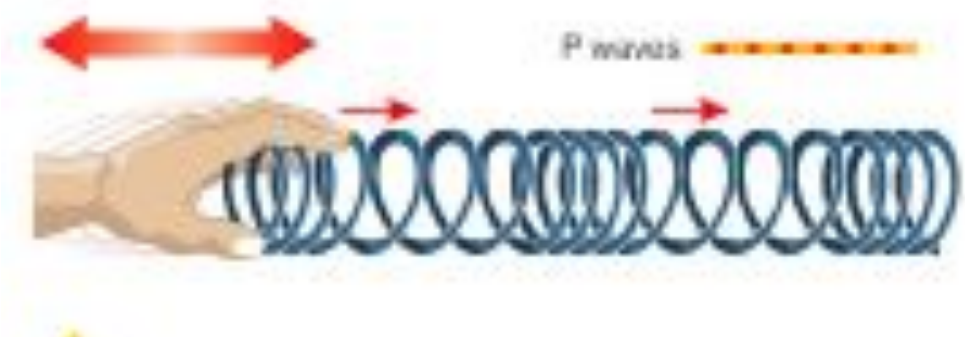
2. **Surface Waves:** travel along the outer layer of the crust (Love and Raleigh)

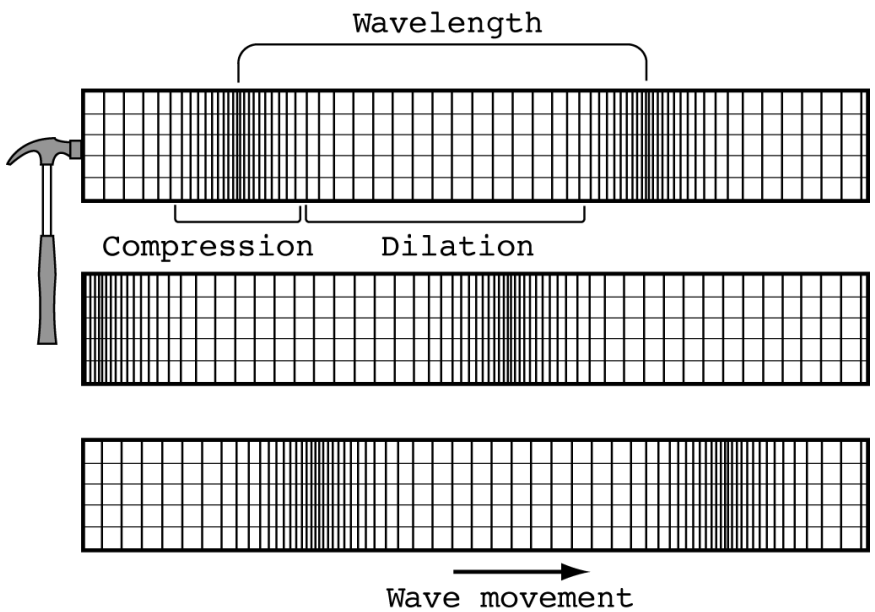
- Ground rolls like a water wave
- Waves travel slowly and cause the most damage.



Seismic Waves: P-waves

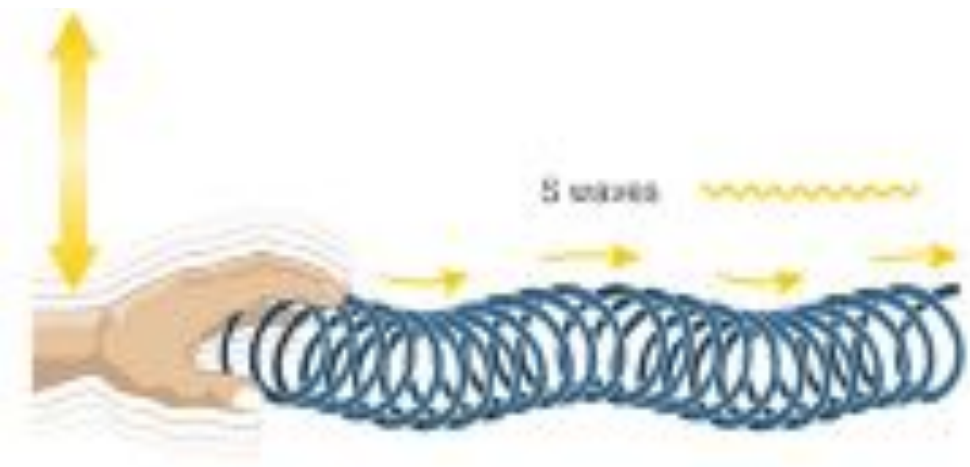
- **P (Primary)** or compressional waves
- Direction of wave is same direction of force
- Fastest waves, travel through Earth's interior

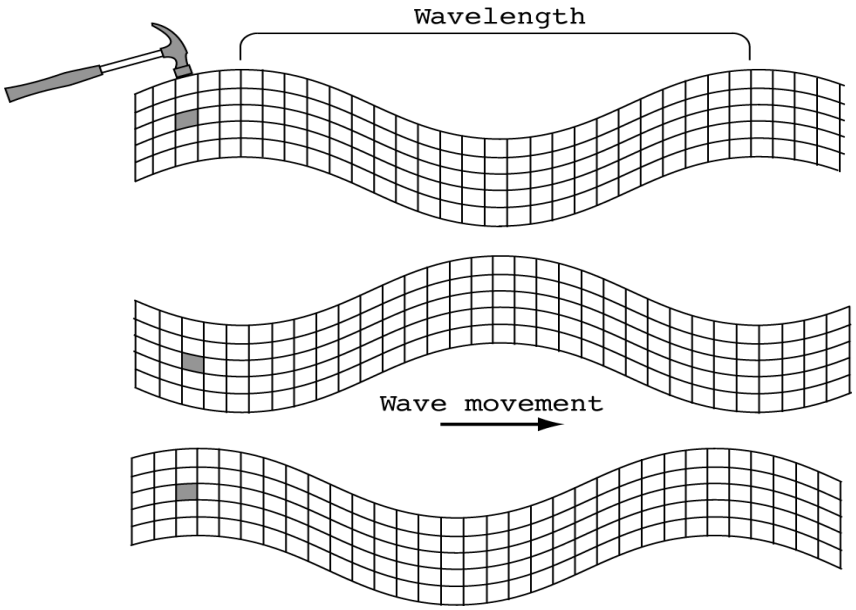




Seismic Waves: S-waves

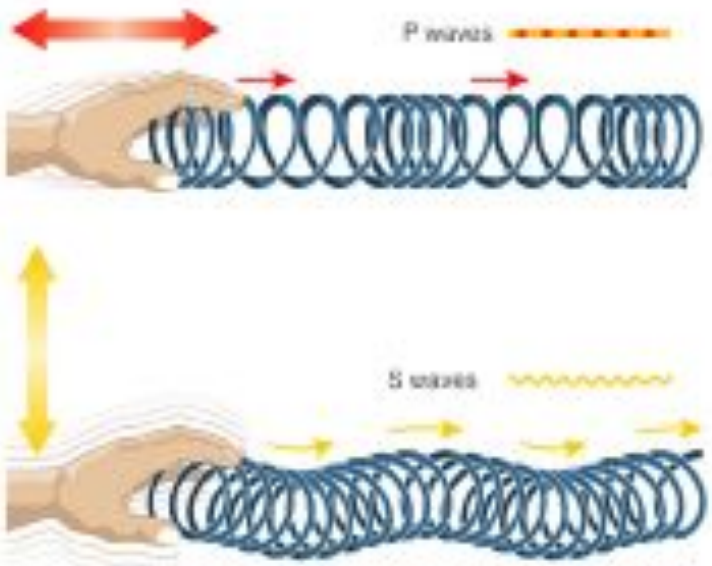
- **S (Secondary)** or shear waves
- Direction of wave is perpendicular to force
- Slower than P, also travel through Earth's interior

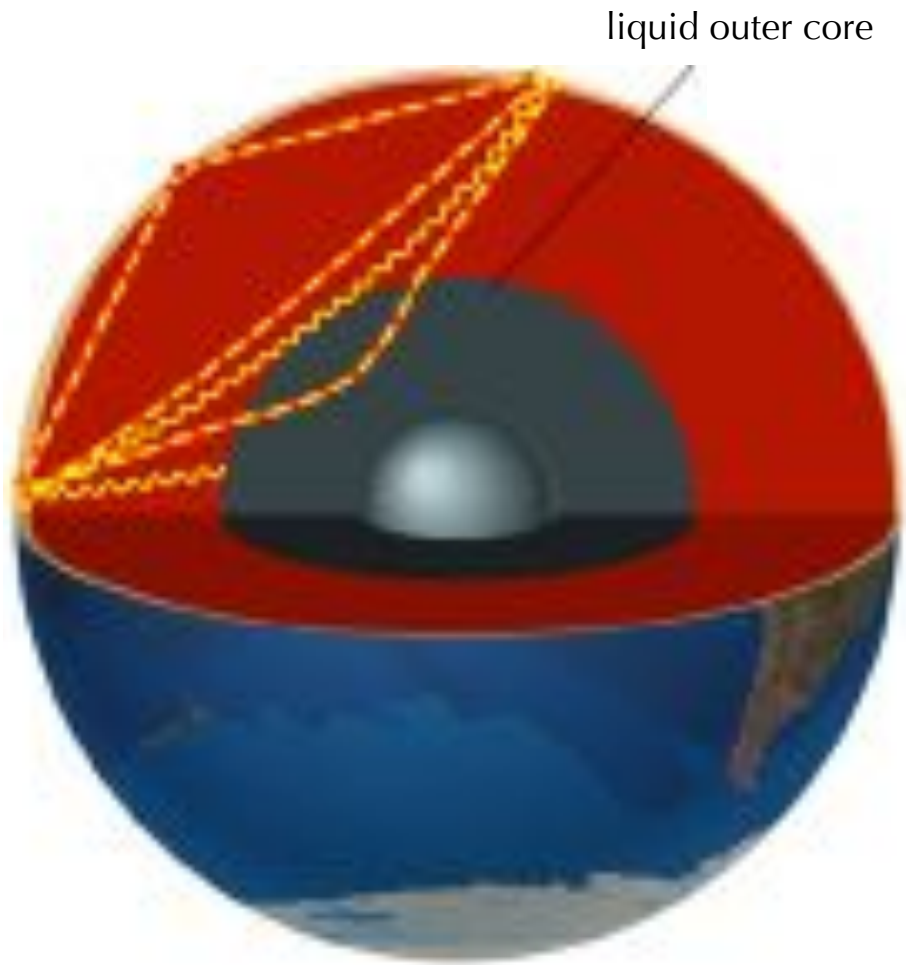




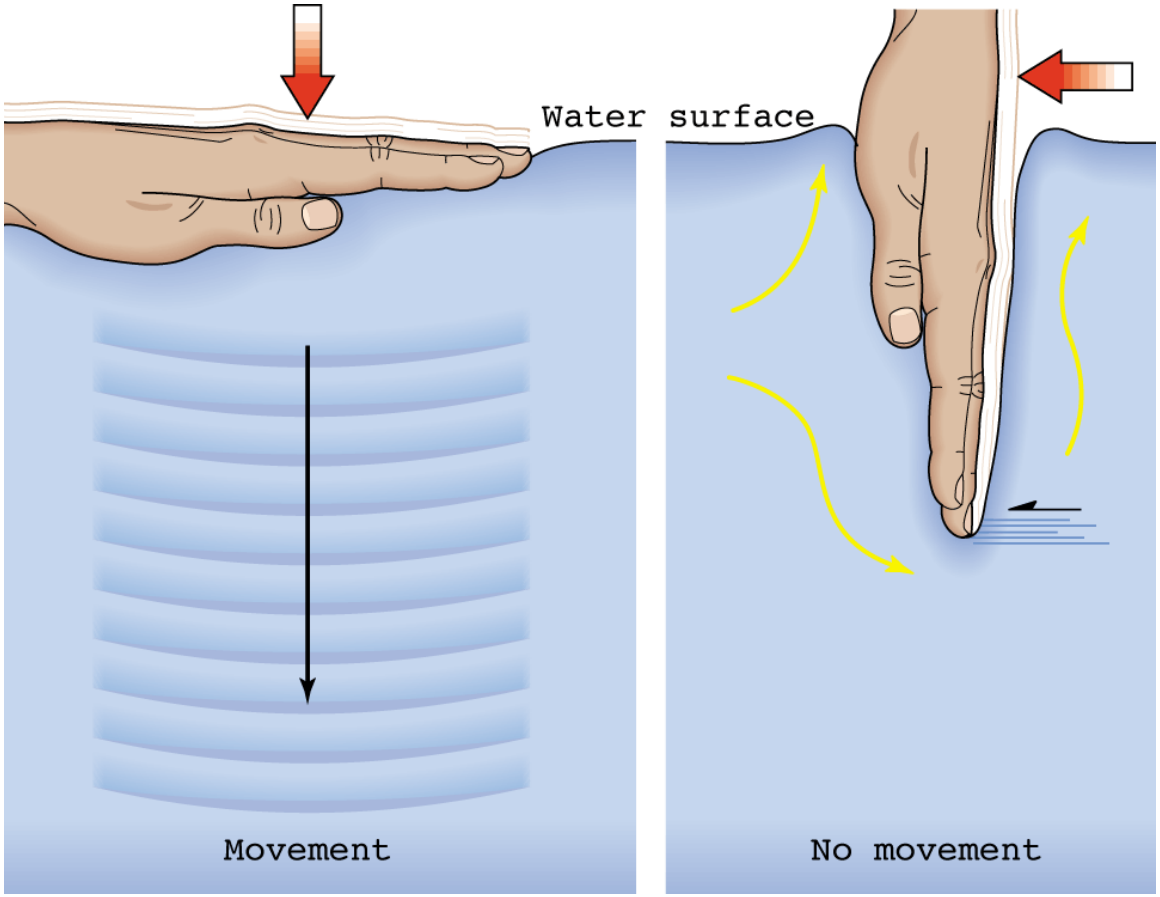
Seismic Wave Observations

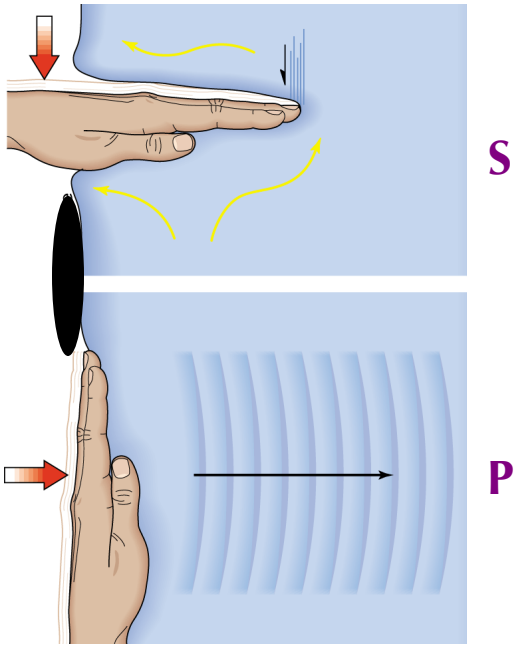
1) P & S waves "bend" as they travel through Earth layers
2) P & S waves can "bounce" off different density layers
3) S waves can't travel through liquid





Seismic Waves and Fluids

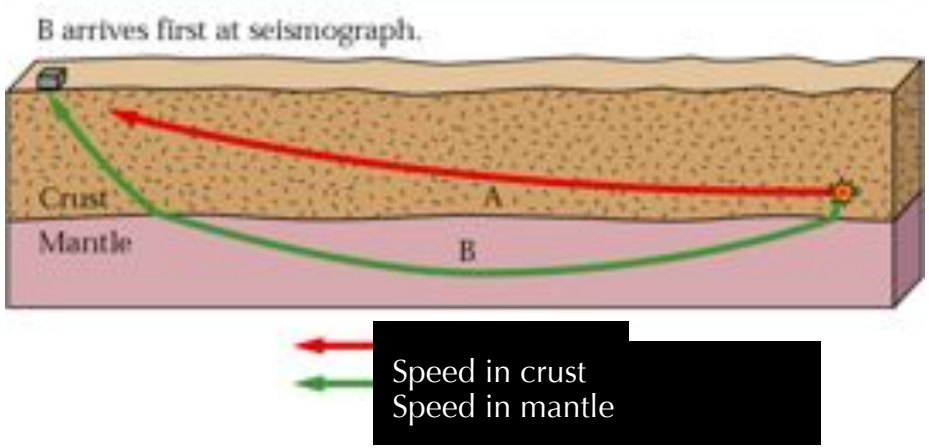




- P waves travel through fluids
- S waves **do not** travel through fluids

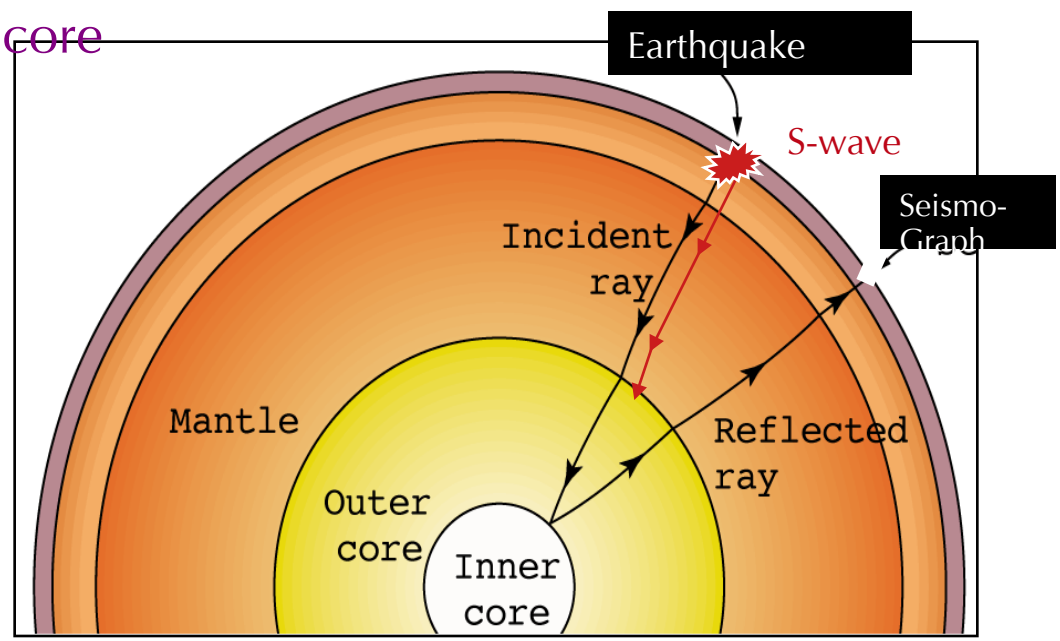
Discoveries about Earth's Interior

- **Crust-Mantle Boundary**
  P and S waves travel **faster** in the mantle: **more dense**

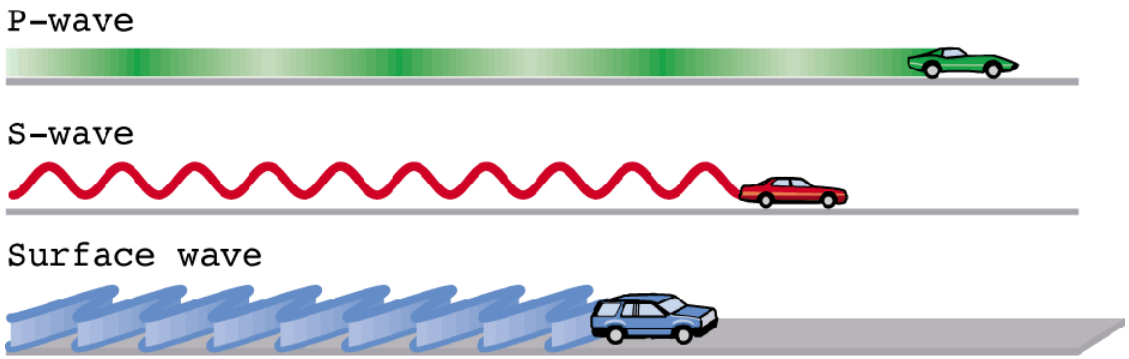


- **Liquid outer core**
  S waves can't travel through liquid core

- **Solid inner core**
  P waves reflect off of solid inner core



Body Waves vs. Surface Waves



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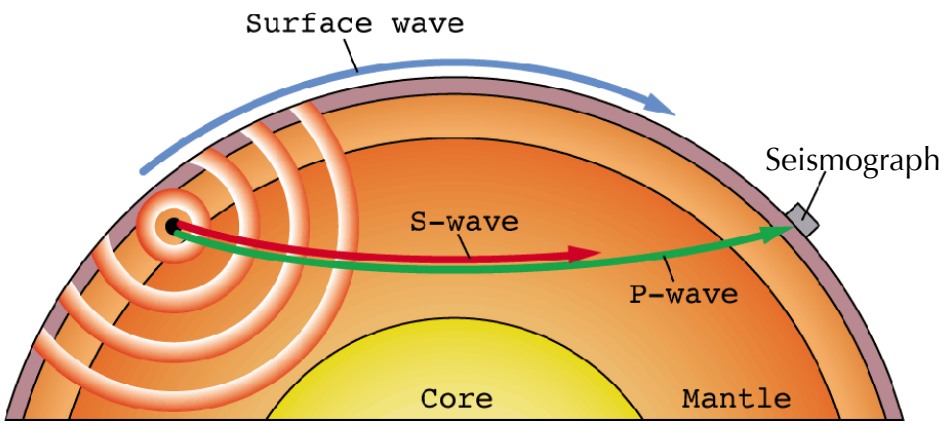
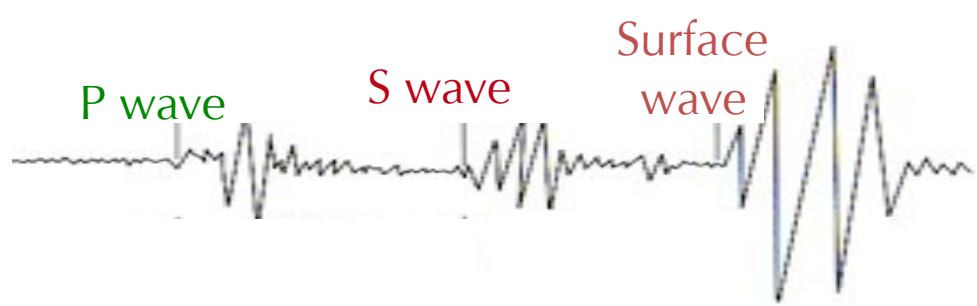
Body Waves





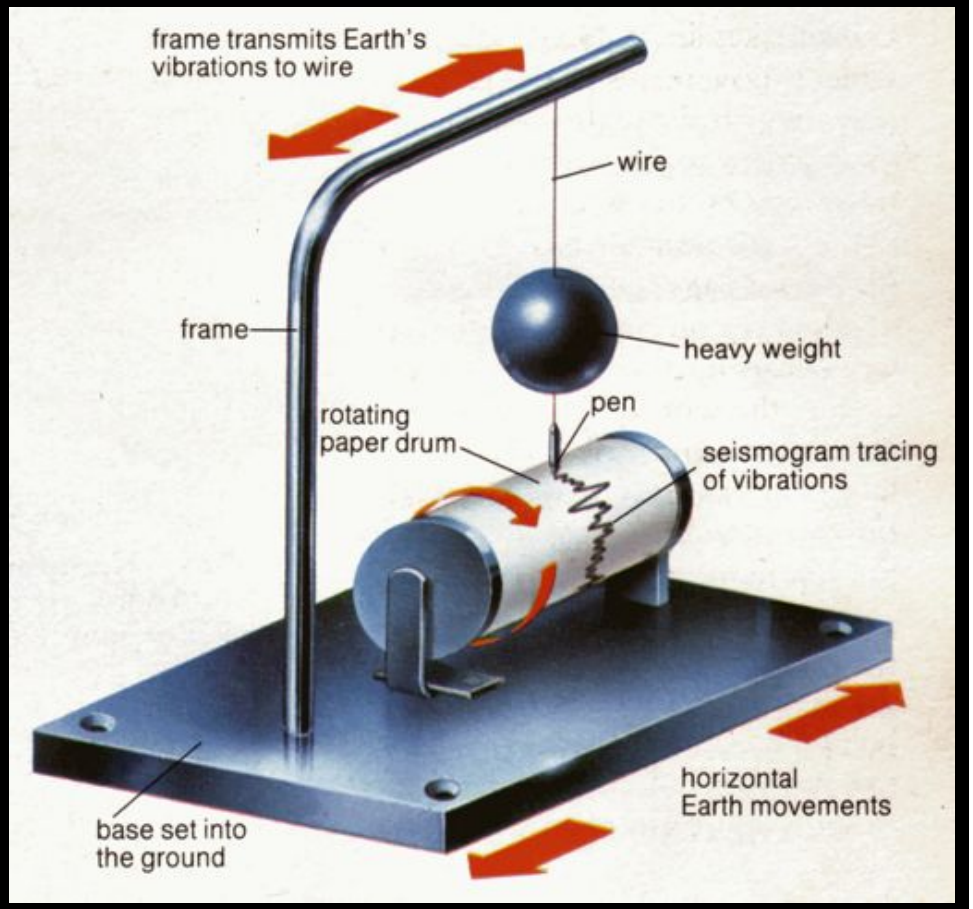
First seismic Instrument: Chang Heng's Seismoscope

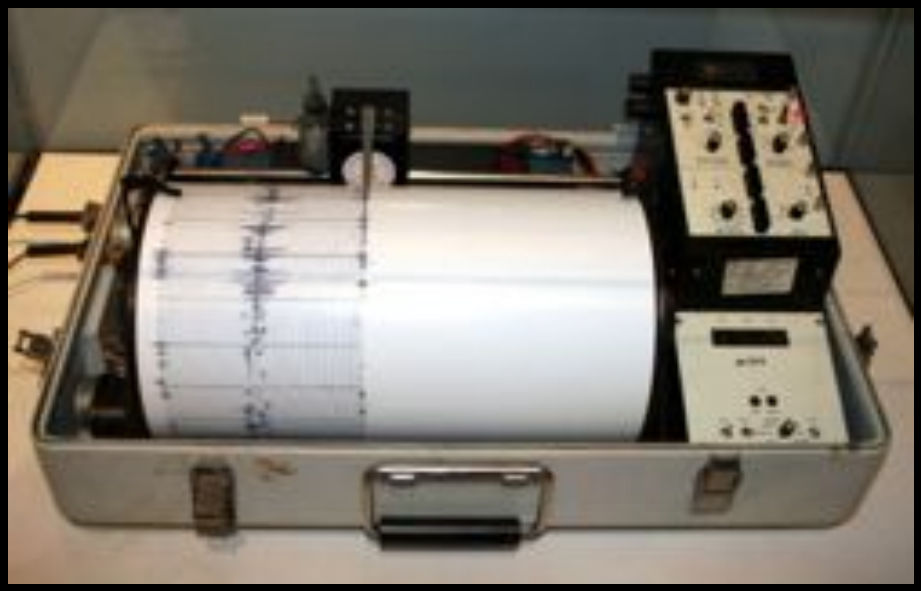
132 AD

Modern **Seismometers** record the ground shaking

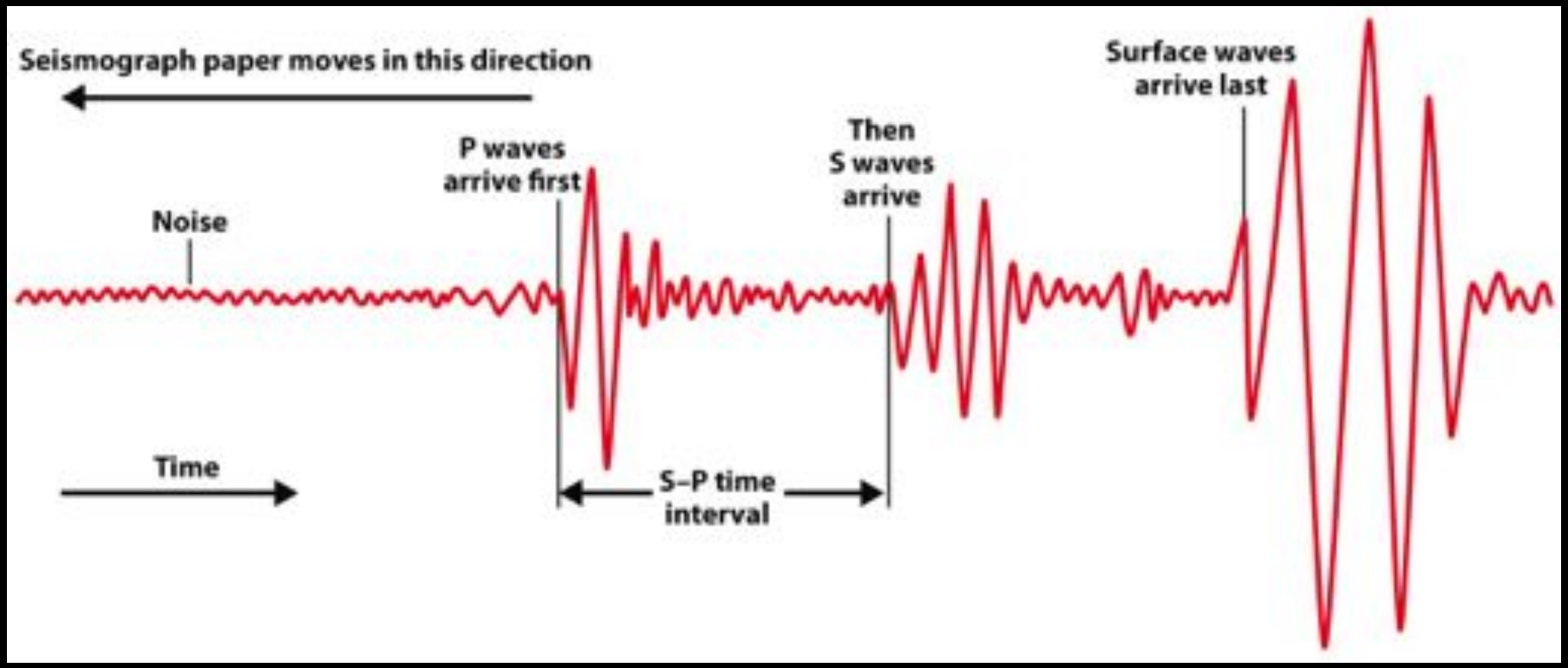
The recording is called a **seismogram**.

Now, seismograms are recorded digitally.





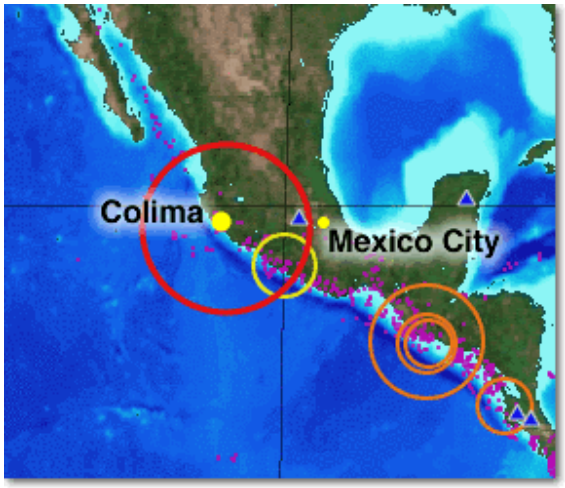
Seismogram is made by a seismometer.



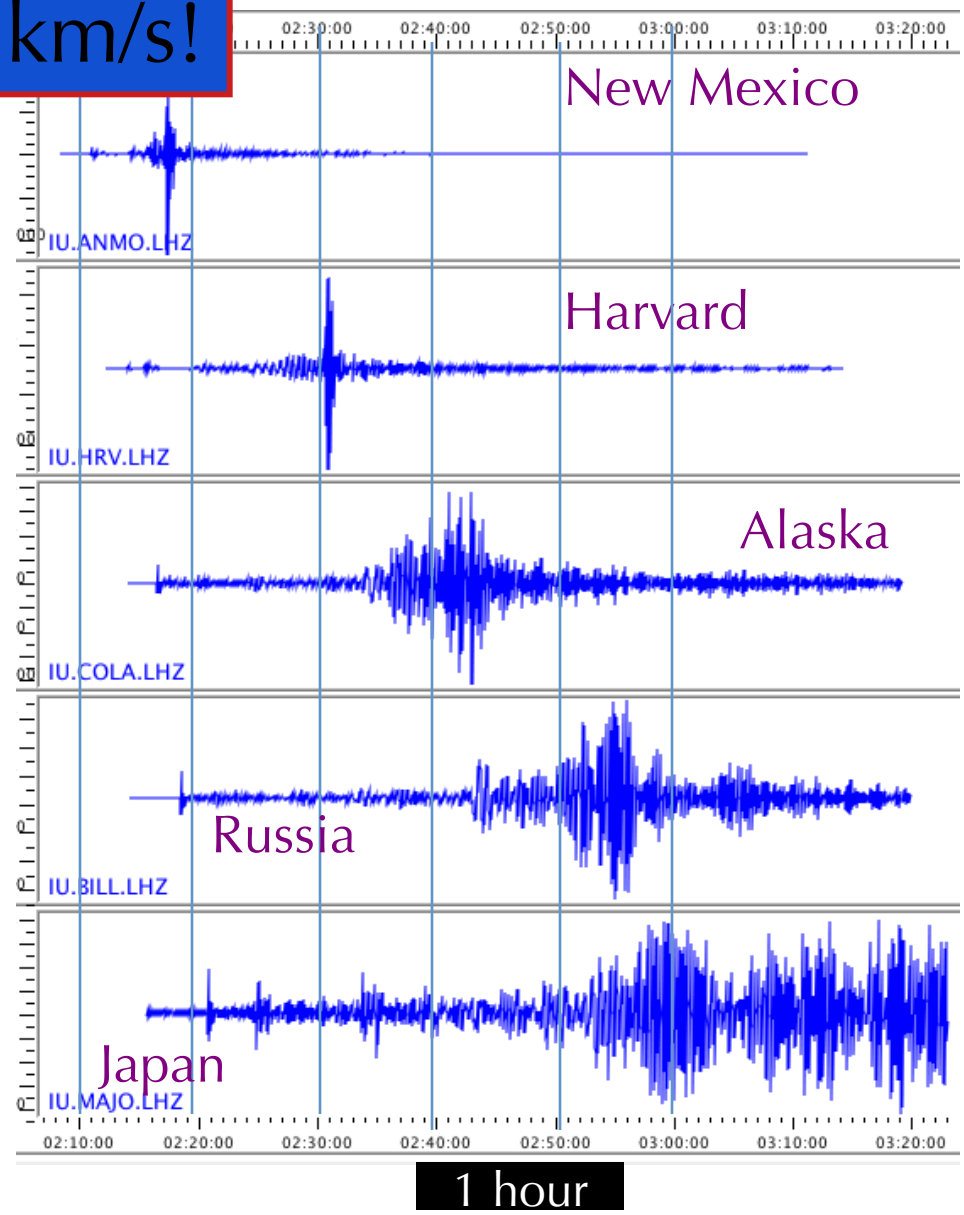
S-P time interval tells us the distance from the epicenter

How fast do seismic waves travel?

4-12 km/s!



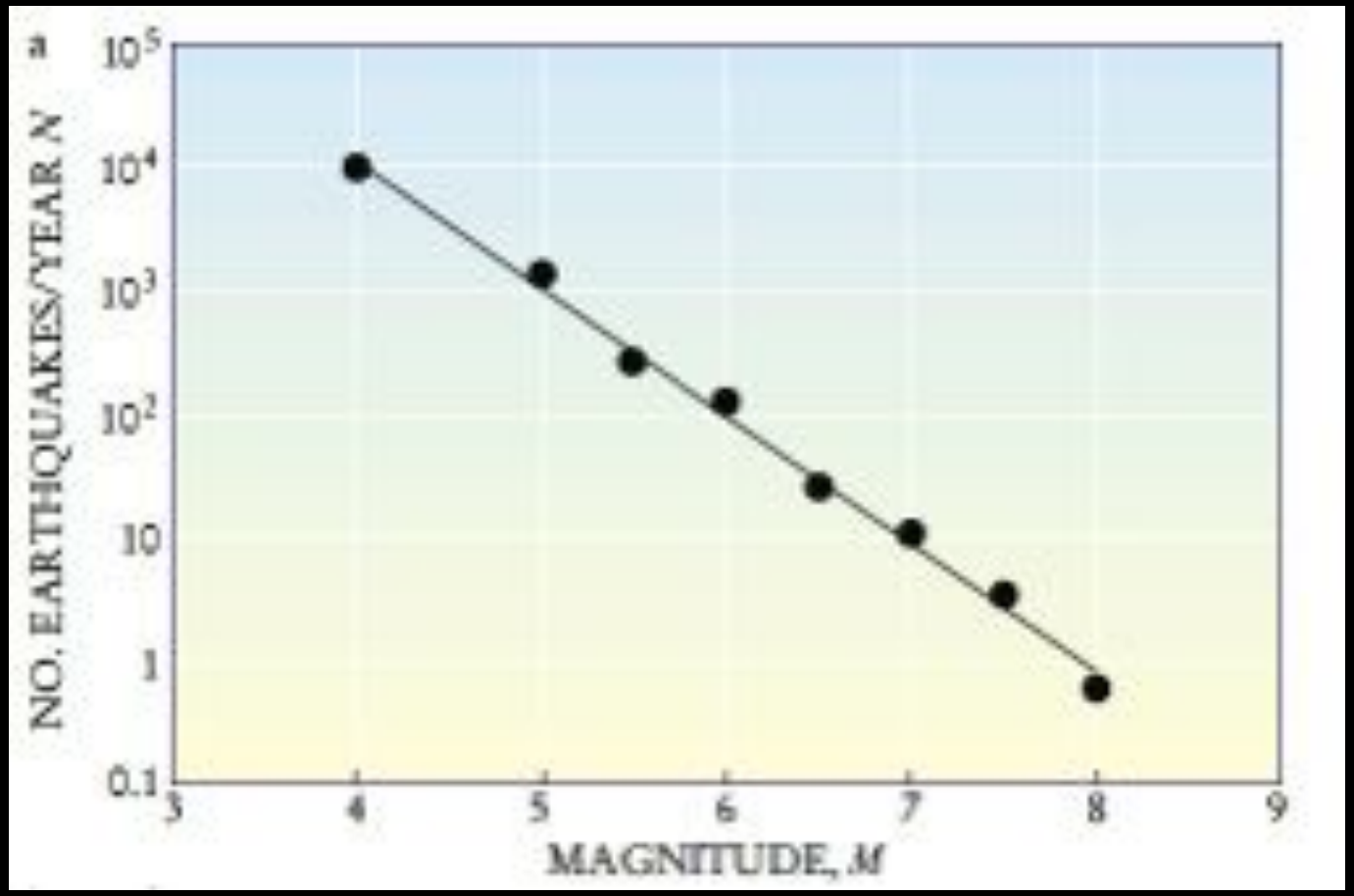
Event: 2003/01/22 02:06:35.8
Mag: **7.8**
Depth: 33.00 km
Description: MEXICO



Note: 1 km/s ~ 2200 mi/hr

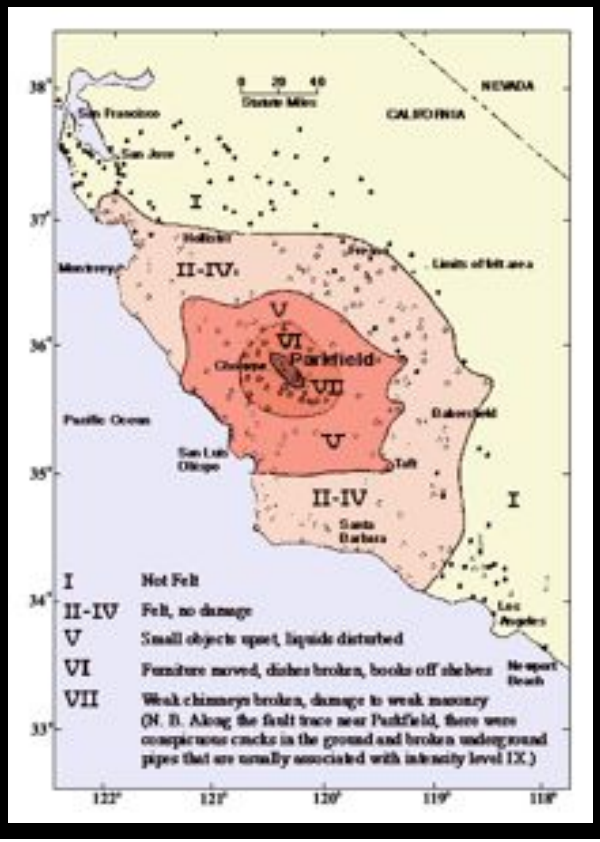
The size of an earthquake is measured by the **Richter Scale**

- Magnitude ranges from 0 to 10
- An increase in magnitude of 1.0 indicates an earthquake that 32 times larger
- There are many more small earthquakes than big ones



Earthquake **Intensity Scale** (Modified Mercalli)

measures the damage caused by earthquakes

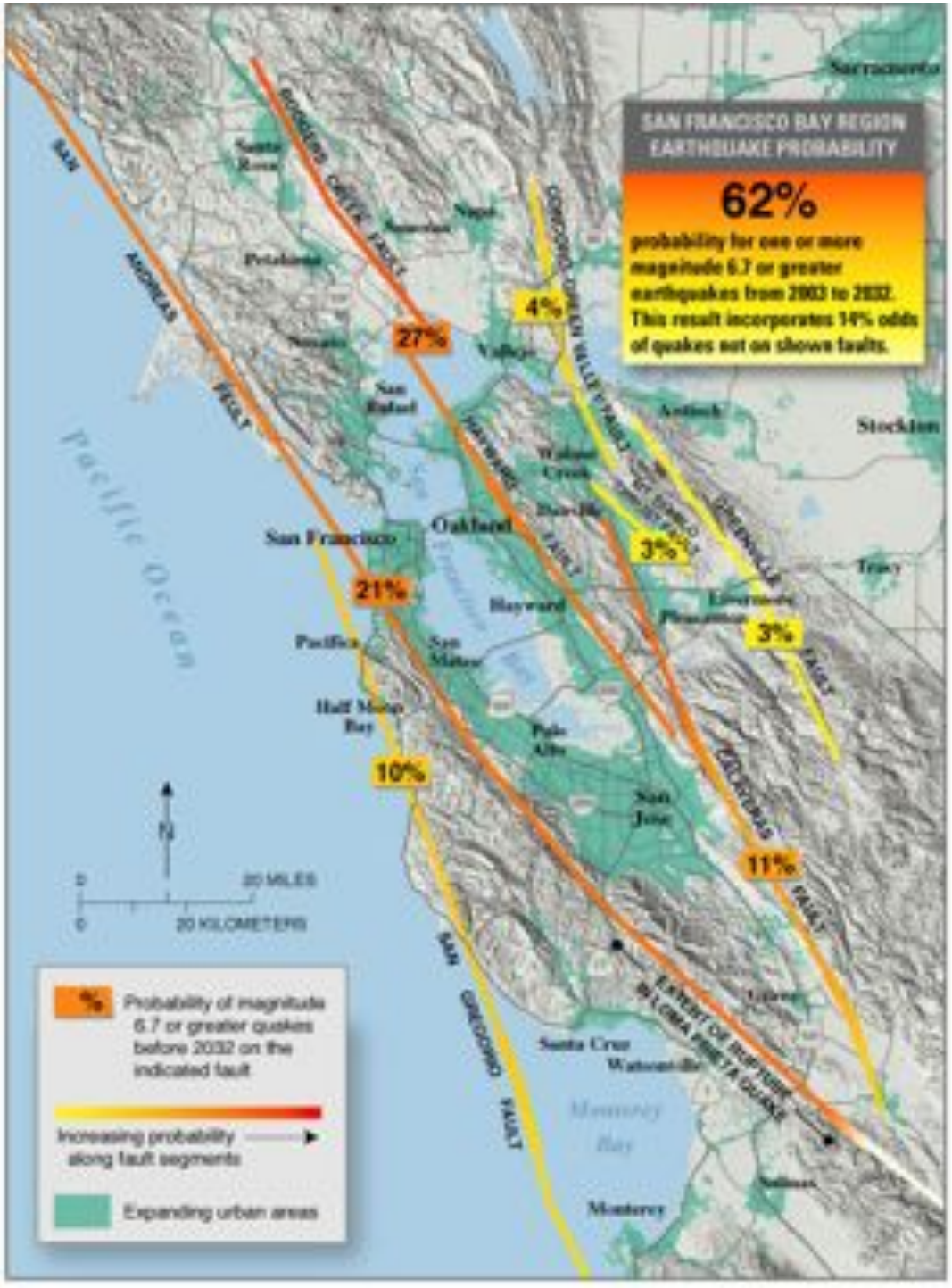


Modified Mercalli Scale		Richter Magnitude Scale
I	Only felt by sensitive instruments	1.5
II	Felt by few persons at rest, especially on upper floors, delicate suspended objects may swing	2.0
III	Felt indoors, but may not be recognized as earthquake, vibrations like large passing truck	2.5
		3.0
IV	Felt indoors by many, some outdoors, may awaken some sleeping persons; dishes, windows, doors may move, cars rock	3.5
V	Felt by most; some windows, dishes break; tall objects may fall.	4.0
VI	Felt by by all, falling plaster and chimneys, light damage but some fear.	4.5
VII	Very noticeable, damage to weaker buildings on fill; driving automobiles notice.	5.0
		5.5
VIII	Walls, monuments, chimneys, bookcases fall; liquifaction; driving is difficult	6.0
IX	Buildings shifted off foundations, cracked and twisted; ground is cracked and underground pipes are broken.	6.5
X	Most structures severely damaged to destroyed; ground is cracked, rails are bent, landslides on steep slopes	7.0
XI	Few structures standing; bridges and roads severely damaged or destroyed, large fissures in ground	7.5
XII	Total damage; can see the earthquake wave move through the ground; gravity overcome and objects thrown into the air	8.0

Earthquake Prediction?

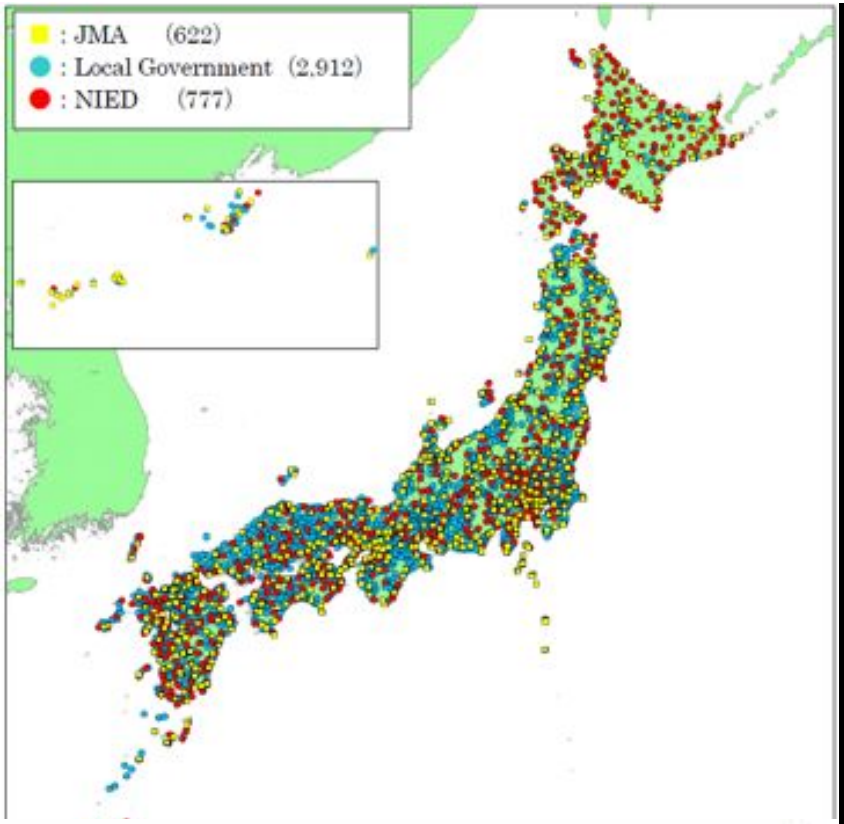
Not possible yet!

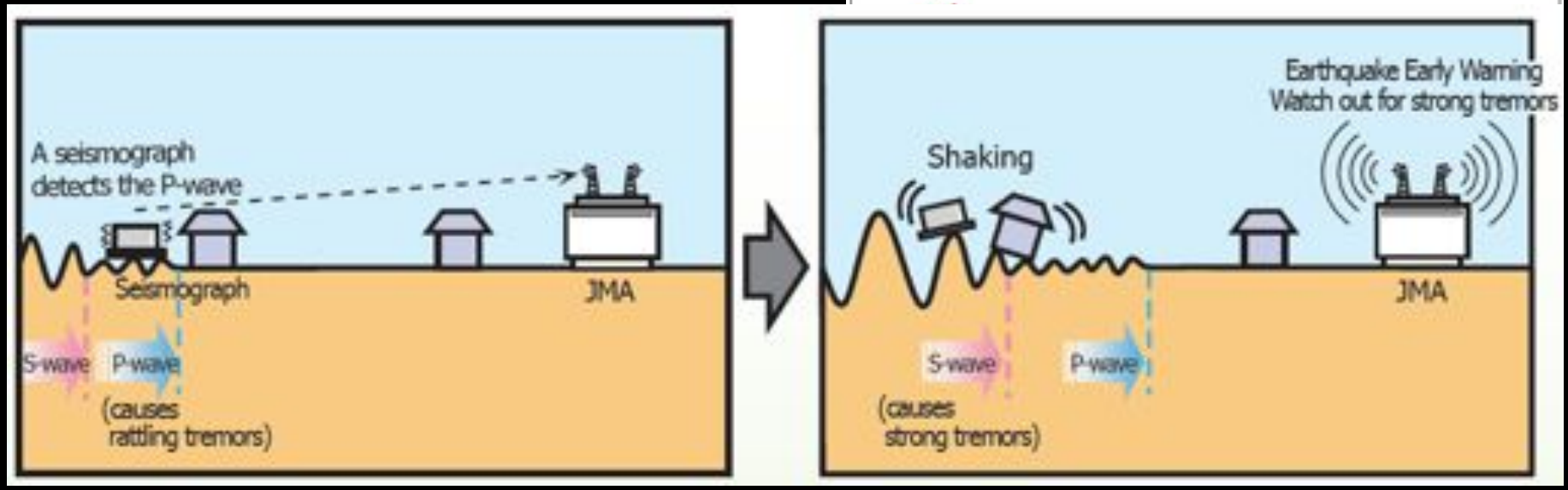
Instead, we have **Earthquake Forecasts**.



Earthquake Warning

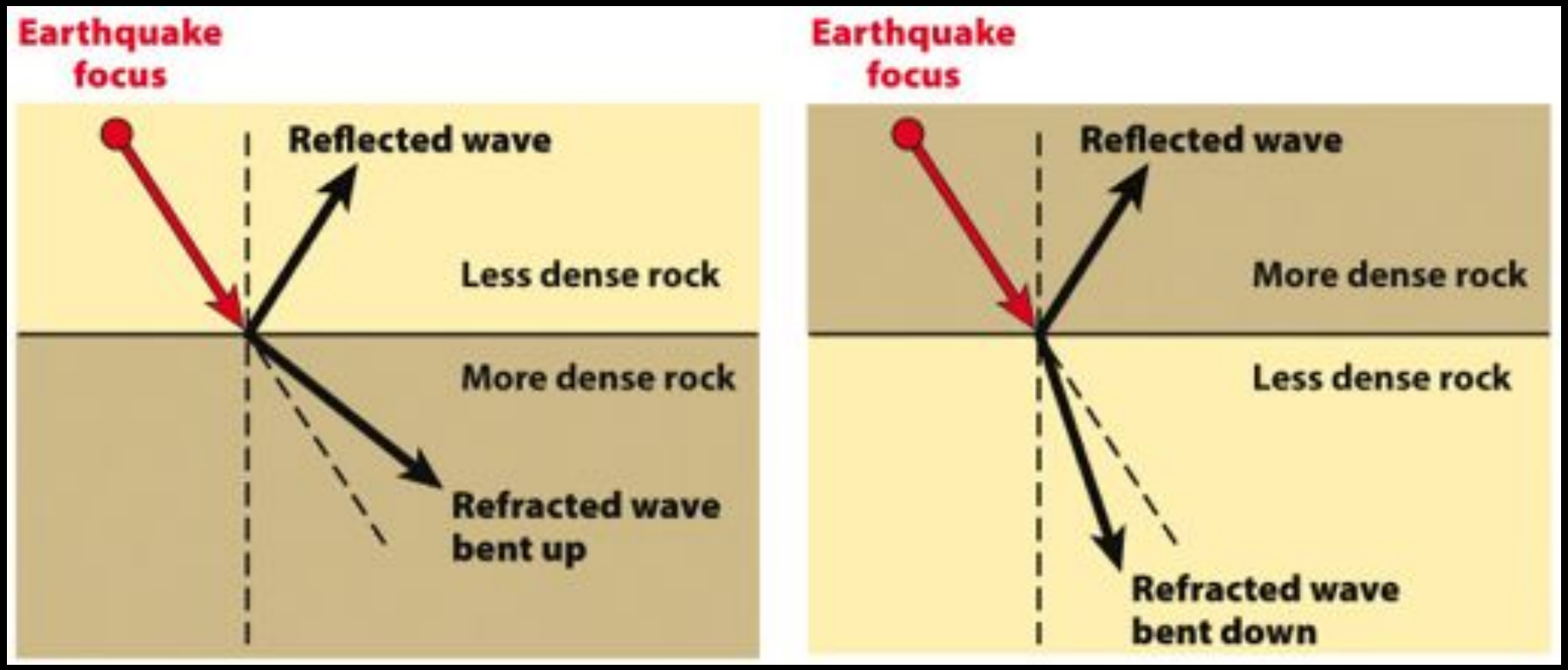
Gives advance warning
of impending shaking
from an earthquake
that has already occurred





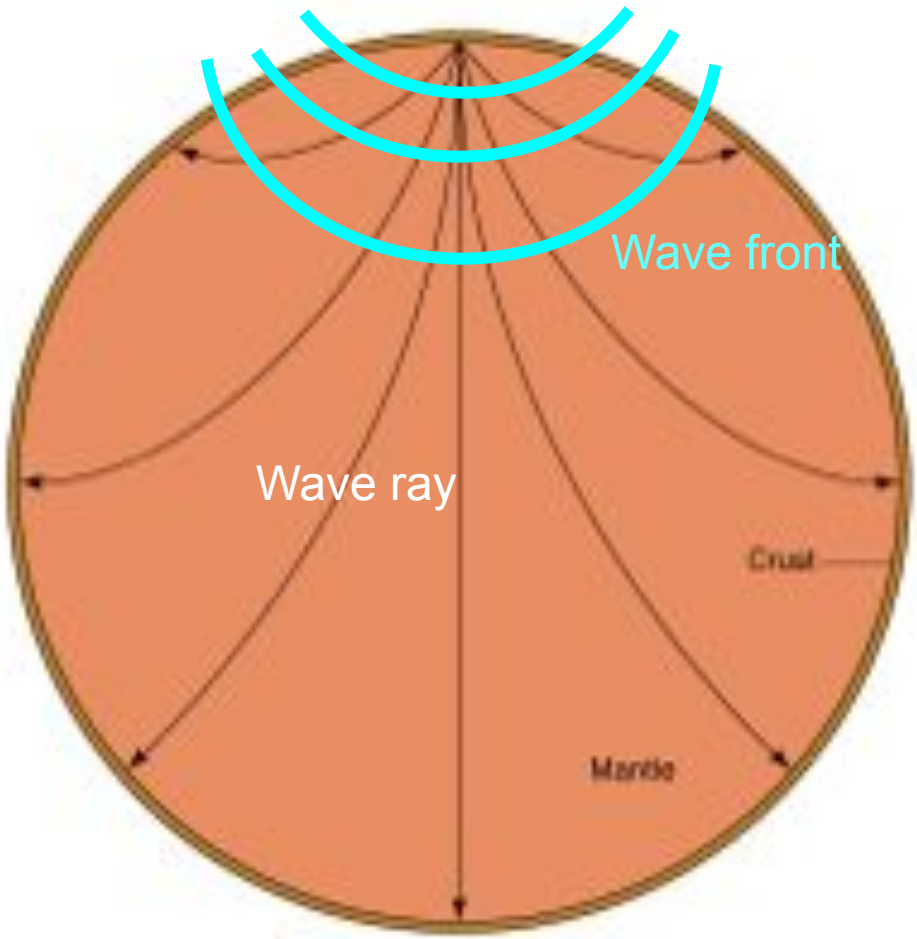
Seismology is the study of seismic waves

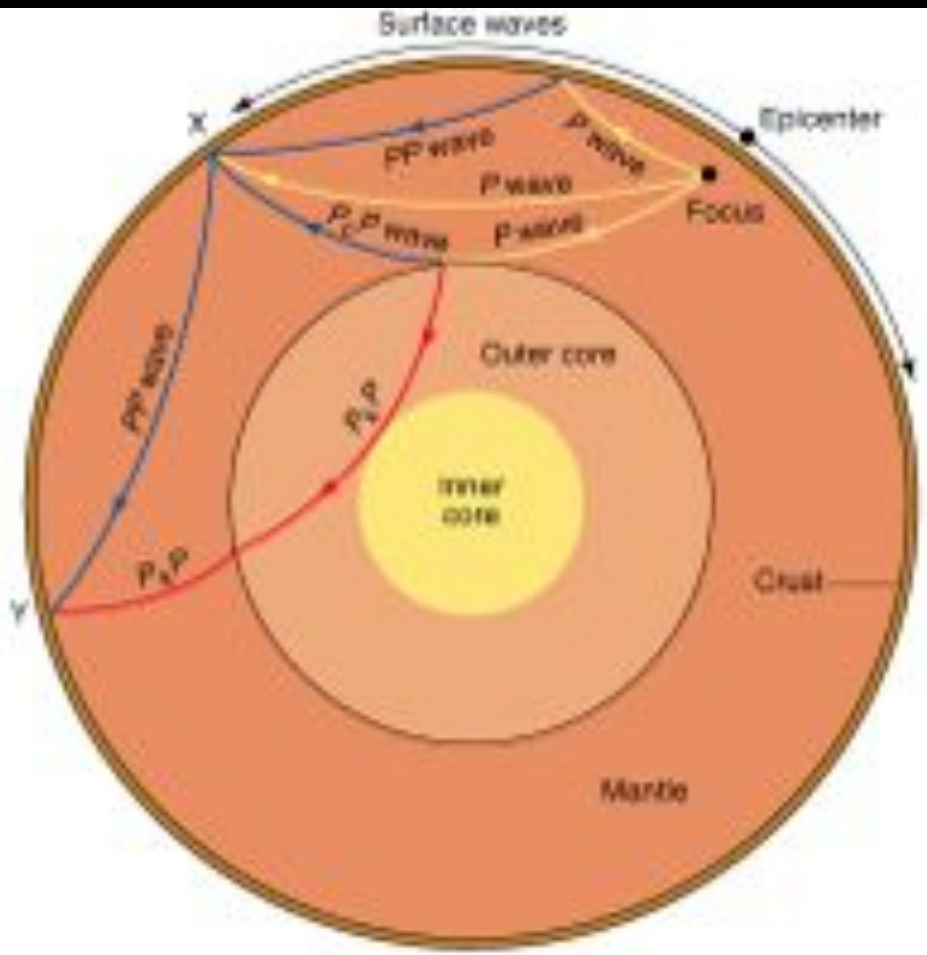
Seismic waves are **refracted** and **reflected** at a discontinuity.



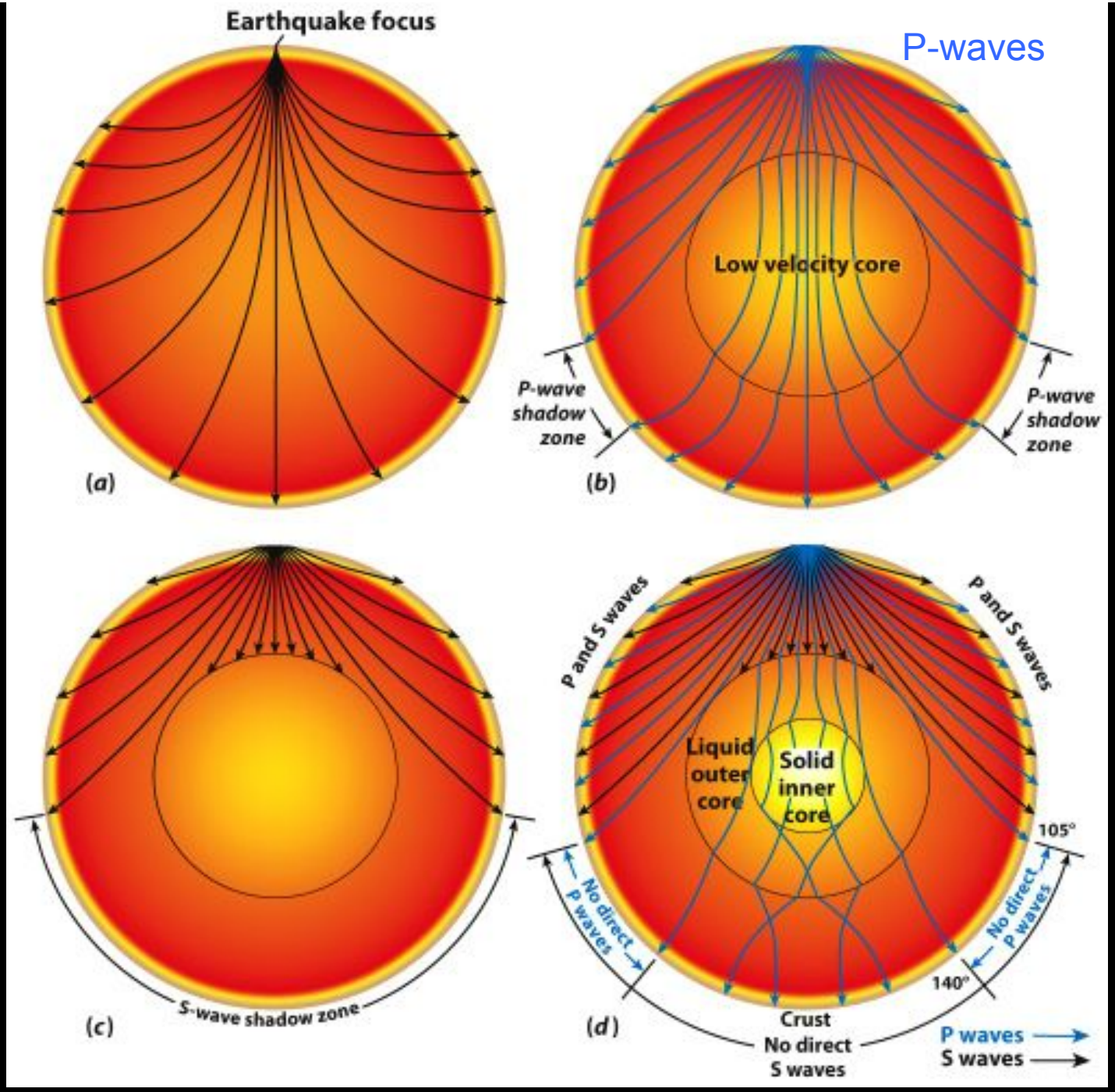
Refraction and Reflection of Seismic Waves

- Waves travel faster through denser rocks
  →this causes upward bending of the waves as they descend through the mantle.
- Waves also reflect off density interfaces.

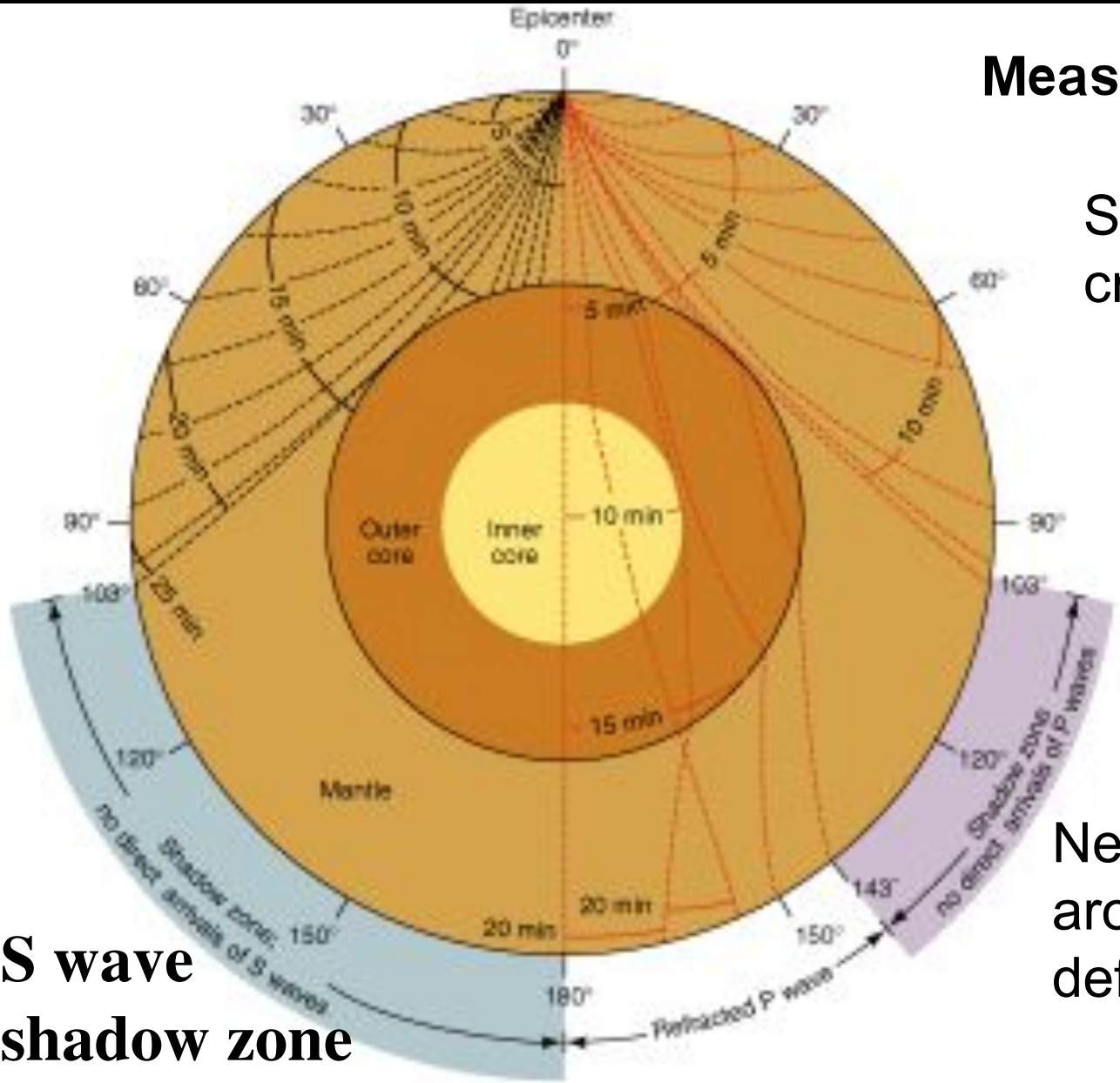




Traveling S- and P-waves through the Earth.



Seismic Shadow Zones



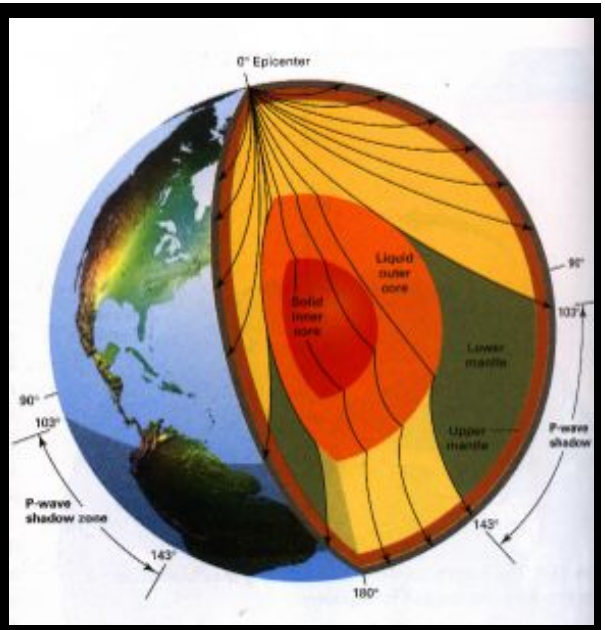
Measuring Earths Interior

S-wave propagation creates a shadow zone

Network of epicenters around Earth's surface defines the interior zones

S wave shadow zone

iClicker Question

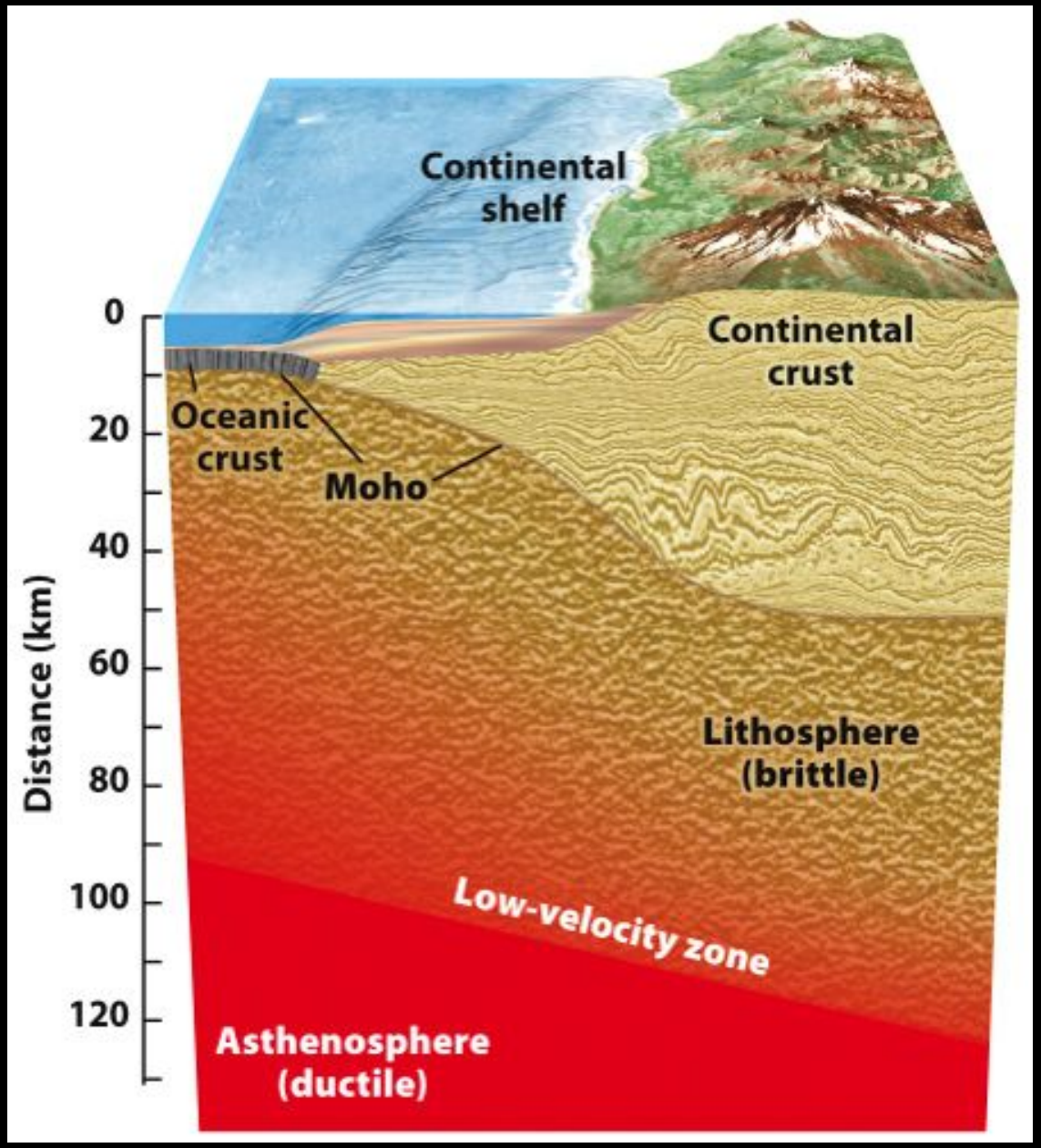


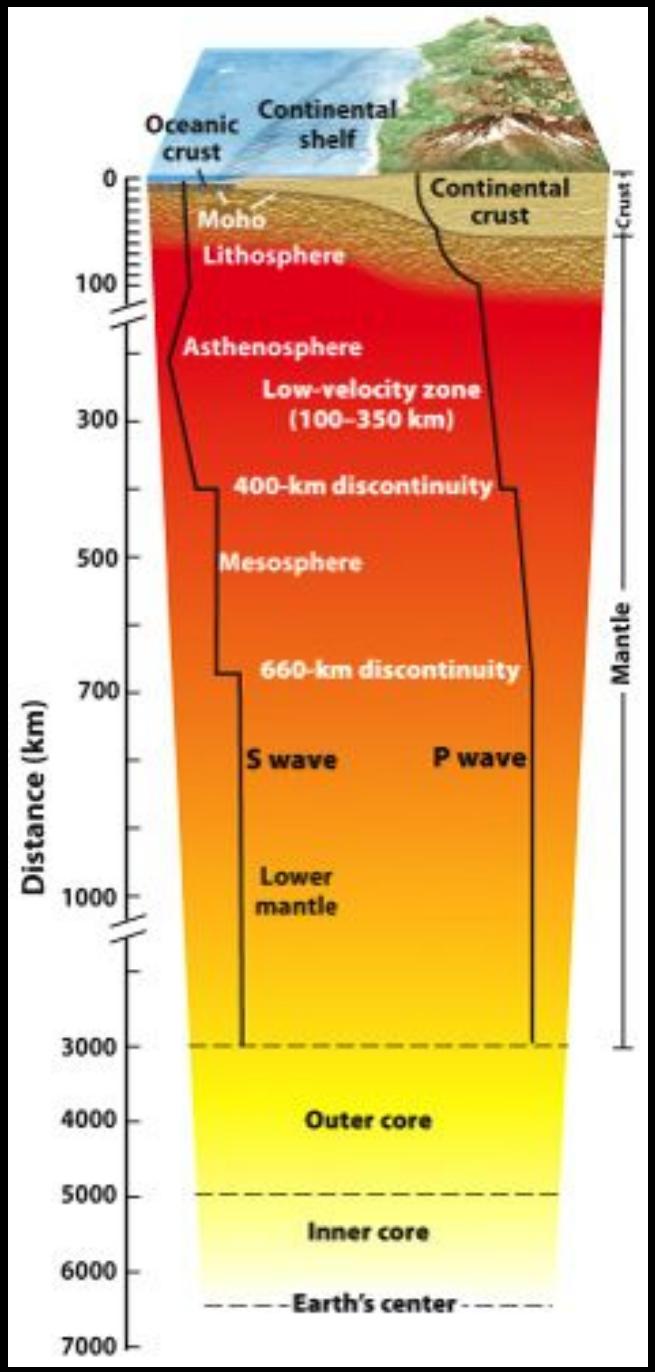
Seismic shadow zones are the result of:

a. Waves absorbed in the liquid outer core
b. A lack of large earthquake.
c. A lack of seismometers in the Southern Hemisphere

Mohorovicic (Moho) Discontinuity

- ~ 8 km beneath oceanic basins
- ~ 20 to ~70 km beneath continents





Seismic data confirm the existence of discontinuities in Earth's interior.

Discontinuities = changes in rock layers

Action Items for Thursday October 15

1. Read Chapter 11
2. Complete homework assignment #13

What you should know from today:

1. Describe different earthquake hazards
2. List 4 types of seismic waves
3. Describe how seismic wave characteristics result in shadow zones
4. Describe seismic tomography and what it reveals about Earth's interior